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VAN. H. MANNING, DIRECTOR

WHY AND HOW COKE SHOULD BE USED FOR DOMESTIC HEATING

BY

HENRY KREISINGER
AND
A. C. FIELDNER

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WHY AND HOW COKE SHOULD BE USED FOR DOMESTIC HEATING.

By Henry Kreisinger and A. C. Fieldner.

INTRODUCTION.

As a part of a general investigation of more efficient methods of utilizing the fuel resources of the country and the elimination of smoke in cities, the Bureau of Mines is conducting experiments on the burning of coke and other fuels in house-heating furnaces, with the object of demonstrating that soft coal can be so prepared by conversion into smokeless fuels, coke and gas, that all the materials in the coal are used to best advantage.

This paper discusses the advantages of coke as a fuel, and points out how coke should be burned in heating houses. The information applies both to gas coke and to by-product coke.

WHY COKE SHOULD BE BURNED.

Coke should be used for heating houses because it is a clean and convenient fuel. It eliminates smoke, reduces the necessity of cleaning the furnace and flues, requires less attention than coal, and gives a more uniform temperature in the house. By burning coke for domestic heating, more soft coal will be used in by-product plants, which save many valuable by-products that are wasted when the coal is used directly in the raw state. The by-products of popular interest obtained in the coking process are gas, light oils, ammonia, and tar.

NEED OF SMOKELESS FUEL.

The only way of eliminating smoke in large cities is by using smokeless fuel—a fuel that will burn without producing smoke in any equipment now in use. In the past the only smokeless fuel available for house heating was anthracite. However, anthracite is mined in only one district in the United States and, therefore, its use is limited to the area lying within reasonable freight distance of the anthracite mines. Much the larger part of the country has to de-

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pend on soft coal for domestic heating. Inasmuch as coking coal can be found in many places in the United States it is possible and desirable that part of the bituminous coal should be converted into coke to supply a smokeless fuel for household use. It is also possible to burn coke in small power plants that can not use mechanical stokers and are situated in the heart of a city where fuel should be burned without smoke.

COST OF SMOKE TO THE COMMUNITY.

The cost of smoke to the community has been investigated in detail in several large cities. The committee on smoke prevention of the Cleveland Chamber of Commerce in 1909 fixed the annual loss due to smoke in the city of Cleveland at $6,000,000, or about $12 for every man, woman, and child each year.

Similar investigations made by the Mellon Institute in Pittsburgh showed a total annual cost of $10,000,000, or about $20 per capita. This estimate does not include such items as depreciation in value of property, compulsory absence of certain industries, injury to health, or impaired mental efficiency.

In view of this large cost of smoke to the city, would it not pay to exert some effort to eliminate smoke by providing smokeless fuel and have a much pleasanter place in which to live and enjoy the good health that goes with a pure, wholesome atmosphere?

CONVENIENCE OF COKE AS FUEL.

When burning coke a furnace requires much less attention than when burning soft coal. The time usually given to poking fires, cleaning the furnace flues and the house, can be spent much more profitably in some other way. Surely the most disagreeable work a householder is called upon to do is to clean the soot out of his furnace and flues. Moreover, the cleaning is not limited to the furnace and flues alone, but extends to the entire house. With hot-air heating, particularly, some of the soot may be carried into the house, necessitating more frequent house cleaning, curtain washing, and papering. The cleanliness of coke will appeal especially to the housewife.

PROMOTING EFFICIENCY IN METALLURGICAL INDUSTRIES.

Using coke in house-heating apparatus will provide the coke producer with a market for the small-size coke, thus allowing him to supply coke of uniformly large size which is needed for metallurgical purposes. Thus, the use of coke in heating houses will improve the fuel efficiency of the metallurgical industries.

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VALUE OF GAS AS A BY-PRODUCT.

When one ton of soft coal is coked in a by-product plant about 5,000 cubic feet of gas is made available for outside use. This gas is particularly well adapted for cooking, ironing, and, where electricity is not availiable, for lighting. It is also a convenient fuel to be used in small gas stoves or, even open grates late in the spring and early in the fall, when the weather is too warm to use the regular furnace and too cold for no fire. A small gas stove can be lighted readily and the room made comfortable for dressing in the morning and for retiring at night. Gas is particularly well adapted for water heaters and for bath-room heating. All these features add to the pleasures of life.

Those housewives who once use gas for cooking appreciate its conveniences and cleanliness; they never want to go back to the dirty coal or wood stove. There is no coal or wood to be carried into the house, no ashes and soot to remove from the stoves and carry out of the house. The ash and soot are always a horror to the housewife, because in cleaning the stove the ash and soot are scattered through the house and mean so much additional work to keep the house clean.

When gas is used for cooking the fire is always ready and the heat can be controlled with a nicety that can not be obtained with any other fuel. Instead of building up the fire and waiting for the stove to get hot before cooking can start, the gas is instantly available for work, thus the housewife is saved a great deal of time. We must appreciate the fact that the housewives, too, want shorter hours.

The readiness of the gas fire for cooking is especially appreciated on hot summer days. With the ordinary coal or wood stoves practically the whole stove must be heated before anything can be cooked on it, whereas with the gas fire only a small flame is burning, and that where the heat is needed, the rest of the stove remaining cool. When any particular cooking process is done the fire can be turned off and no fuel is wasted. Such is not the case with a coal fire. The first must be left burning until it burns out, unnecessarily heating the kitchen and making it uncomfortable. Oftentimes the fire must be kept going between the cooking of two meals. Thus the efficiency of the gas fire is very much higher than the coal fire. Although the cost of heat in the form of gas may be ten times as much as the cost of heat in the coal, it may be cheaper in the end to burn the gas, because it is used so much more efficiently.

Aside from the efficiency of the gas, the comfort of the housewife demands consideration. She also wants to have her work made lighter and more pleasant. The man equips his shops and

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offices with the latest, most up-to-date, labor-saving machinery, frequently without consideration of the cost. Why should not the housewife be allowed to share the benefits of modern improvements and inventions? Instead of allowing her to perspire around the coal stove that her grandmother used, why not provide her with a modern gas fire for cooking and for heating water for cleaning and washing, thus making her work lighter and her life more pleasant?

Gas can not be made to sell at a reasonable price for household use unless the by-product, coke, is fully utilized. Only by selling a large quantity of coke for house-heating purposes can the by-product plant operator afford to deliver the gas to the householder at a reasonable price.

VALUE OF LIGHT OIL.

The process of coking 1 ton of soft coal yields about 3 gallons of light oils suitable for motor fuel. At present prices the heat in the light oil has about 20 times the commercial value of the same amount of heat in the form of coal. When our mineral supply of oil is exhausted soft coal will be our chief source of motor fuel. The light oil recovered from coking soft coal now supplies part of the ever-increasing demand for motor fuel. It may be added here that during part of the war, Germany was practically cut off from every supply of mineral oil. She depended for her motor fuel entirely on her coal. As a result of that condition Germany sent most of her coal through by-product coking plants. What has been done in Germany may in the future have to be done in the United States.

When soft coal is burned in house-heating furnaces most of the light oil escapes unburned and is wasted. By converting the coal into coke and using coke as a house-heating fuel the light oil obtained as a by-product helps to replenish our decreasing supply of motor fuel. A part of the light oil consists of toluol, which in time of war can be separated from the remainder of the light oil for the manufacture of TNT. Modern warefare requires enormous quantities of this substance for making high-explosive shells. There should be an adequate supply of toluol for national protection. During the first part of the war the Allies came near defeat for the lack of this material. Utilization of the light oil tends to reduce the cost of converting coal into smokeless fuel.

VALUE OF AMMONIA.

The ammonia that is recovered in the process of converting soft coal into coke is used for various purposes. Its chief value lies in its nitrogen content, 17 pounds of ammonia containing 14 pounds of

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nitrogen. One of the most important uses of ammonia is in making artificial fertilizers. More fertilizer means more productive farms, which are especially desirable in the thickly populated industrial States where a large quantity of food is needed. If the food is produced where it is used, transportation charges are eliminated, and thus the cost of food is materially reduced. Hence the coking of coal in by-product plants produces large quantities of ammonia for fertilizer, and thus helps to reduce the cost of living. Ammonia is also used in artificial ice making, cleaning, and in the manufacture of nitric acid. Nitric acid is used for making explosives for mining coal.

When soft coal is burned in its raw form in any kind of furnace, the ammonia, which contains the nitrogen of the coal, escapes into the air and is wasted. It has been frequently proposed to build large hydraulic power stations to generate cheap electricity and use the electricity to obtain nitrogen from the air. Why should soft coal be burned in a raw state, discharging all its contained nitrogen into the atmosphere, and then expensive hydraulic plants be built to get back from the atmosphere part of the nitrogen wasted in burning the raw coal? Why not get the nitrogen directly from the coal by coking in a by-product recovery plant? Burning coke to heat houses encourages the development of this economical use of coal and the production of cheap ammonia.

VALUE OF COAL TAR.

Coal tar is used in the manufacture of a large number of drugs, dyes, explosives, paints, wood preservatives, road dressing, roofing and building papers, and a great variety of other useful articles. The number of new articles made from coal tar are increasing daily. Coal tar is also used successfully in place of fuel oil for metallurgical purposes. In fact, it seems that the usefulness of coal tar has been barely touched.

When soft coal burns in house-heating furnaces most of the tar escapes unburned and is not only wastetd but pollutes the atmosphere with very sticky dirt. Coking the soft coal in by-product plants provides smokeless fuel for heating houses and recovery of the useful tar.

INCREASED VALUE OF PRODUCTS OF THE COKING PROCESS.

When 1 ton of soft coal having a market price of $7 per ton is coked in a by-product plant the chief products obtained have the value shown in the following table:

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TABLE 1.—*Value of by-products obtained by coking 1 ton of coal.*

Cost of 1 ton of coal	$7.00
1 ton of coal produces—	
0.65 ton of coke, worth	6.00
5,000 cubic feet of gas, worth	5.00
3 gallons motor oil, worth	.75
9 gallons tar, worth	.25
25 pounds ammonium sulphate, worth	1.25
Total value of products	13.25
Less cost of 1 ton of coal	7.00
Increased value	6.25

The table shows that the products of the coking process have a market value about 90 per cent greater than the original coal. This increased value is due mainly to the human labor expended in the coking process, because it takes a great variety of labor to plan, build, and operate a by-product plant. High technical skill—that of engineers, chemists, and draftsmen—is required in making the plans for a by-product plant, a large number of skilled and unskilled workmen are needed to erect the plant, and a large number of skilled and unskilled workmen are necessary to supply the material needed in its erection. Skilled and unskilled labor has to distribute to consumers the by-product gas; a large number of technical men, and skilled and unskilled labor is needed to operate the plant; and many chemists are kept busy getting drugs, dyes, paints, and other products out of tars. Therefore, by using coke, employment is given to a large number of men. The increased value of the products represents the labor that has been expended in making these products available.

The use of bituminous coal will develop in much the same way as waste in meat packing has been eliminated. Thirty years or more ago a large amount of material from the slaughtered cattle was thrown away and thus not only was largely wasted but became a nuisance by polluting streams and the atmosphere. At present everything from the slaughtered cattle is utilized; the packing industries employ thousands of skilled and unskilled workmen, and the meat-packing centers are no more a horror to the inhabitants of the surrounding country.

In the past soft coal has been burned in the raw state in dwelling houses and in many plants not equipped for its efficient utilization. A large part of the valuable substances in the coal escaped as black smoke, was wasted and polluted the atmosphere. In spite of the efforts that were exerted to improve the furnace in order to obtain

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smokeless combustion the smoke largely persisted. Now people are realizing that the smoke from a chimney is a warning to man that he is not using the coal as he should. Times are changing; a large part of the soft coal output of the country is sent through the by-product plant, and substances that were previously wasted as smoke are now turned into valuable products, and at the same time a smokeless fuel (coke) is made available for burning in almost any kind of heating apparatus.

HOW TO BURN COKE IN HOUSE-HEATING EQUIPMENT.

KINDLING A FIRE.

For starting a fire in an ordinary furnace or boiler in a 6 to 10 room residence about 10 to 15 pounds of kindling wood is needed. When the wood is well ignited it should be covered with a layer of coke about 6 inches thick. It will usually take one hour to get this first layer of coke burning nicely. All the available draft should be used to start a fire; the stronger the draft the sooner the fire will start. After the first layer of coke is well ignited the furnace should be filled to a depth of 14 to 18 inches, and the draft checked to allow the coke to burn slowly.

DRAFT.

To get good results from a coke fire the draft must be kept under control. The amount of draft required depends on the weather conditions and the size of the coke. Generally speaking, it takes much less draft to burn coke than it does to burn anthracite or bituminous coal. If too strong a draft is used after the fire is started, the coke will burn too fast, making the house too hot and requiring frequent firing. Proper regulations of the draft is therefore highly essential.

The draft is regulated mainly with three dampers, designated in figure 1 by the letters A, B, and C. Damper A is in the smoke pipe connecting the furnace with the chimney. This damper usually consists of an opening covered with a hinged lid. When this lid is closed the full draft of the chimney is effective in the furnace. When the lid is lifted the chimney draws air from the cellar instead of drawing the gases out of the furnace, and the draft in the furnace is reduced almost to nothing. In some furnaces the damper in the smoke pipe is of the form shown by D. When the damper D is open the full draft of the chimney draft becomes available in the furnace; when it is closed the draft in the furnace is reduced almost to zero. Some furnaces and boilers are equipped with both damper A and damper B. Either one can be used to regulate the chimney draft.

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The damper B on the ash-pit door regulates the flow of air through the fuel bed, and the amount of air flowing through the fuel bed determines the rate of combustion, which is the amount of coal that the furnace can burn in an hour. Therefore, to control the rate of combustion and thereby regulate the amount of heat the furnace delivers to the house, the furnace attendant adjusts the damper in the ash-pit door and the check damper in the smoke pipe. In many furnaces the ash-pit door fits so loosely that enough air flows into the ash pit, even when the damper in the ash-pit door is closed. In fact, this leakage may be so great that keeping a fire over night may be difficult. If this is the case the leakage of air into the ash pit should be stopped by refitting doors or dampers or closing openings and cracks with cement or "smooth-on."

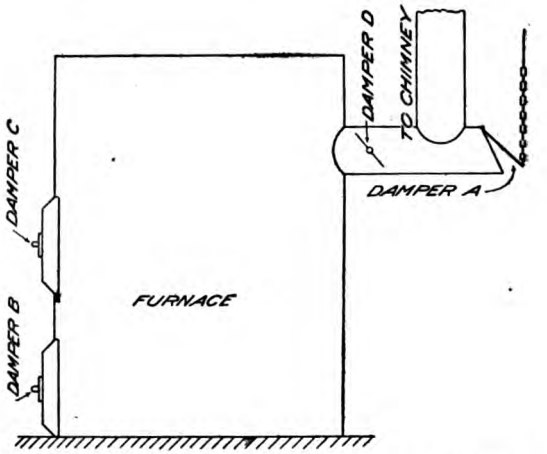

FIGURE 1.—Position of dampers in a house-heating furnace. Damper *A* regulates the draft in the furnace and should be used with dampers *B* and *C*. Damper *B* regulates the supply of air through the grate and the rate at which the coal burns. Damper *C* regulates the supply of air over the fire and the completeness of combustion. Damper *D* controls the draft and should be used with damper *A*.

The damper C in the firing door supplies air over the fire, this air being needed to burn the combustible gases rising from the fuel bed, and regulation of the damper controls the completeness of combustion. In many furnaces and boilers the damper and the firing door fit so loosely that enough air enters into the furnace for complete combustion even when the damper is closed. An opening of about one-eighth inch in the average damper will be enough.

THICKNESS OF FUEL BED.

If the size of the furnace will permit the fuel bed should be carried about 18 inches thick. A thick fuel bed helps to check the draft and gives slow uniform combustion and uniform temperature in the

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house. With a thick fuel bed the fire will last a long time without requiring attention. If a thin fuel bed is carried the coke burns too fast, giving a hot uneven fire that burns out quickly and requires frequent firing. A thin fire also tends to produce more clinkers.

SHAKING THE GRATE.

A coke fire requires less shaking of the grate than a coal fire. In ordinary weather one shaking a day, preferably in the morning, is all that will be necessary. In very cold weather the grate may have to be shaken before each firing. Usually better results are obtained when the grate is not shaken too much, and it should never be shaken so much that pieces of hot coke fall into the ashpit. Therefore in shaking the grate the ashpit should be watched and the shaking should stop as soon as the first sparks appear in the ashpit. Some people who have burned coke for many years say that they get better results if they leave a layer of ashes about 1 to 2 inches thick on the grate all the time. The ashes help to check the draft and keep the hot coke from coming in contact with the grate. Between firings the fuel bed should be stirred as little as possible.

REMOVING CLINKERS.

If clinkers form on the grate they should be pulled out just before firing. Usually the best time to remove clinkers is in the morning, when the fire is started for a day's run. It often happens that this one cleaning is sufficient, and sometimes the fire may go two or three days without removing the clinkers, particularly if the weather is mild. The less the fire is disturbed the better satisfaction is obtained with coke.

The ash should not be allowed to accumulate in the ashpit until it reaches the grate, for then the grate will be injured. Therefore it may be well to remove the ash from the ashpit every day.

SIZE OF COKE.

The best size of coke for house-heating furnaces and stoves is between one-half inch and 2 inches. If a larger size is used the coke burns too fast and requires more frequent firing. For open grates the size of the coke may be somewhat larger, ranging from one-half inch to 4 inches. It should be remembered that coke is much lighter than anthracite and bituminous coal. Therefore a greater bulk of coke should be fired at a time than when burning coal. Pieces of coke are more angular and have rougher surfaces than pieces of bituminous or hard coal, hence the latter can be packed more tightly in the fuel bed

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than those of coke. Consequently the spaces between the pieces of coke are much larger than those between the pieces of coal and allow much freer passage of air. This is why coke requires less draft than either soft or hard coal. To make the coke pack more tightly on the fuel bed and reduce the spaces between the individual pieces it may be advantageous after firing to tap the coke down with a poker. This patting will also permit of firing more coke at a time than if the coke is thrown in loosely with a shovel and the fire will go longer without attention.

BANKING THE FIRE.

For banking the fire over night, the fines from the coke pile should be used. The fines make a denser fuel, reduce the draft through the fuel bed, and thus help in keeping the fire over night. The fuel bed may be made still denser by lightly tapping the coke on top with a poker or shovel. The ash pit door should be closed as tightly as possible and the draft in the furnace reduced by opening the check damper in the smoke pipe. If the ash pit door does not fit tightly, in order to keep the fire over night it may be necessary to open the damper in the firing door.

STARTING THE FIRE IN THE MORNING.

In the morning, if a good bed of hot coke about 6 inches thick is on the grate, the grate may be shaken, clinkers removed, the fire leveled, and a heavy charge of coke placed in the furnace. Opening the damper in the ash pit and closing the check damper in the smoke pipe will help to start the fire quickly. After about half an hour, when the freshly fired coke has been well ignited, the damper in the ash pit door can be nearly closed and the check damper partly opened. The magnitude of the opening of the check damper depends on the severity of the weather and on the available chimney draft, and must be determined to suit each individual furnace.

If the fire is almost burned out in the morning, it is well not to shake the grate or remove the clinker, but level the fire with a poker, slightly stirring it so as to shake some of the ashes down in the ash pit, and then fire about a 6-inch layer of coke, open the damper in the ash pit, close the check damper in the smoke pipe, and also close the damper in the fire door. In about half an hour the thin layer of freshly fired coke is well ignited and a heavy firing can be put in to last the greater part of the day. If there is an excessive amount of ash or clinker on the grate the grate can be shaken and the clinker removed through the firing door before putting in the heavy firing.

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FIVE RULES TO BE OBSERVED.

The directions for burning coke can be condensed into five rules, as follows:

1. Carry a deep bed of fuel; a bed about 18 inches thick gives best results.
2. Use very little draft after the fire is started and keep it always under control.
3. Do not stir the fuel bed; clean the fire in the morning, if possible.
4. Use sized coke; ½ to 2 inches for furnaces, boilers, and stoves; ½ to 4 inches for open grates.
5. Do not allow ashes to accumulate in ash pit.

ADVANTAGES OF COKE AS HOUSE-HEATING FUEL.

Coke is a smokeless and clean fuel and offers the best means of making our large cities smokeless. It is known that in large cities where soft coal is burned for domestic heating about 60 per cent of all the smoke in the atmosphere is made in the residential section in house-heating furnaces. Substituting coke for soft coal will eliminate this 60 per cent of smoke. The smoke made in house-heating furnaces is much more objectionable than the smoke made in industrial plants because it is made in the residence section where it does the most harm.

Coke does not make any soot, consequently the cleaning of boilers, smoke pipes, and flues is eliminated. Those who spend their Saturday afternoons or Sundays cleaning furnaces and flues will appreciate this advantage. Soot is a poor conductor of heat; when it is deposited on the heating surfaces of the boiler or furnace much less heat is utilized in heating the house, and a large part of the heat passes up the chimney. All formation of soot means a direct loss, because it represents that much unburned coal.

Soft coal can never be burned in house-heating furnaces with such completeness of combustion as coke. When soft coal is used most of the volatile matter distilled from the coal escapes from the furnace unburned in the form of soot, tar, and combustible gases. Part of the soot and tar is deposited on the heating surfaces of the stove or furnace and in the flues and part escapes through the chimney as visible smoke. The unburned gases go up the chimney with the visible smoke. The tar and soot do not burn in the furnace because the furnace is usually too small and the temperature too low for maintaining their combustion. The residue left after the tar and soot have been driven from the coal is in the form of coke. It burns slowly and almost completely in the small furnace and the heat

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which gets into the house is mostly the heat that has been generated by burning this residue.

Therefore, when soft coal is burned in the ordinary house-heating furnace the coal is first reduced to coke by driving off the volatile matter, most of which escapes unburned; then the coke burns in the furnace and heats the house. Driving off the volatile matter unburned not only causes a direct loss of heat but causes a great deal of dirt in the furnace, flues, boiler room, and also in the outside atmosphere. Since the volatile matter in soft coal is of negative value so far as heating the house is concerned, it is better to use a fuel that does not contain volatile matter. Such a fuel is coke. Most of the coke on the market for domestic heating is made in special furnaces by driving off the volatile matter. From this volatile matter are obtained gas, tar, and other by-products that have a high market value. Therefore, by converting the coal into coke in these special coking plants the volatile matter, instead of being a nuisance, is turned into a source of national wealth.

Results of investigations of the value of different fuels, including coke, anthracite, and soft coals of various kinds, as fuel for house-heating furnaces will be published in a separate bulletin by the Bureau of Mines. The results obtained thus far show that coke can be burned in house-heating furnaces much more efficiently than soft coal.

The results obtained with coke under a steam boiler of a size to supply 800 square feet of radiation are summarized in Table 2.

TABLE 2.—*Results of tests with by-product coke.*

Proportion of boiler capacity developed.	Average period between firing.	Duration of tests.	Overall efficiency.
Per cent.	*Hours.*	*Hours.*	*Per cent.*
52	4	96	73
88	4	120	72
122	3	120	63

The table shows that more than 70 per cent of the heat in the coke was usefully employed in heating the house.

Some time ago the engineering experiment station of the University of Illinois made comparative tests of by-product coke, gas-house coke, Pocahontas coal, and Illinois coal. The results of these tests are printed in Bulletin No. 19 of the University of Illinois. Table 3 gives the summary of results of tests obtained with a boiler capable of supplying 800 square feet of radiation:

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TABLE 3.—*Results of tests of various fuels in house-heating boilers.*

(Tests made at the engineering experiment station of the University of Illinois.)

Fuel.	Efficiency of boiler and furnace.	Fuel fired at each firing.	Average interval between firing.	Rated capacity developed.
	Per cent.	*Pounds.*	*Hours.*	*Per cent.*
By-product coke	61.63	75	3.71	64.46
Gas-house coke	56.22	75	3.21	65.48
Anthracite	51.93	75	2.47	66.00
Illinois coal, Williamson County	48.00	75	2.92	64.04
Pocahontas coal	46.51	75	3.30	63.88

This table shows that with coke about 61½ per cent of the heat in the fuel was utilized in heating the house, whereas, with Illinois coal, only 48 per cent of the heat was utilized. Hence if the coal and the coke contained the same amount of heat, about 7¾ tons of coke will deliver as much heat into the house as 10 tons of the soft coal. In addition to this higher efficiency from coke, the furnace and boiler room are kept clean with less work and there is no smoke to pollute the atmosphere.

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BULLETIN 40. The smokeless combustion of coal in boiler furnaces, with a chapter on central heating plants, by D. T. Randall and H. W. Weeks. 1912. 188 pp., 40 figs.

BULLETIN 58. Fuel briquetting investigations, July, 1904, to July, 1912, by C. A. Wright. 1913. 277 pp., 21 pls., 3 figs.

BULLETIN 76. United States coals available for export trade, by Van. H. Manning. 1914. 15 pp., 1 pl.

BULLETIN 85. Analyses of mine and car samples of coal collected in the fiscal years 1911 to 1913, by A. C. Fieldner, H. I. Smith, A. H. Fay, and Samuel Sanford. 1914. 444 pp., 2 figs.

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